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RUBIES AND SAPPHIRES

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BY

I. AITKENS

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RUBIES AND SAPPHIRES [1]

By I. Aitkens [2]

GENERAL DESCRIPTION

The precious stones rubies and sapphires are transparent varieties of the mineral corundum. Essentially they are aluminum oxide, but the aluminum is often replaced by small amounts of chromium, titanium, or iron. The chromium is said to give a red color, titanium a blue, and iron a yellow.

True rubies range from rose to a somewhat purplish red and are sometimes termed "oriental rubies" to distinguish them from spinel rubies, stones of inferior hardness, density, and value. "Oriental rubies" are very rare, and the so-called "pigeon's blood" variety is the most valuable.

Sapphires normally range in color from palest blue to deepest indigo, but actually all precious varieties of corundum of any other color than red are called sapphires. The most esteemed tint is like that of the blue cornflower.

Colorless corundum of gem quality is called white sapphire; the yellow variety is described either as yellow or as golden sapphire; and the pale pink is classed as pink sapphire. The word "oriental" is also used as a prefix in naming varieties of corundum of less popular colors. For instance, oriental emerald is used for green corundum, oriental topaz for yellow, and oriental amethyst for violet to purple varieties.

The chief physical characteristics of rubies and sapphires are hardness, adamantine luster, and moderately high specific gravity (3.9 to 4.1). Next to the diamond, corundum is the hardest of all minerals; in fact, the sapphire is number 9 on Moh's scale, ranking between the topaz and the diamond.

Rubies crystallize in 6-sided prisms terminated by flat faces and other varieties of corundum with twelve inclined faces, six above and six below, meeting in a girdle. Corundum is doubly refractive, with a direction of single refraction running parallel to the edge of the prism. The refractive indexes are very constant, the ordinary index ranging from 1.766 to 1.774 and the extraordinary index from 1.757 to 1.765. The double refraction always remains the same.

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[1] The Bureau of Mines will welcome reprinting of this article, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6471."

[2] Rare Metals and Nonmetals Division, U. S. Bureau of Mines.

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Heat tends to lighten the color of the stone, the pale violet or yellow losing their tint entirely and the deep violet turning rose color. Radium has an intensifying action upon the coloring. On exposure to high temperature sapphires usually lose color but unlike rubies do not regain it upon cooling. Under artificial illumination sapphires appear dark and inky, and in some instances the blue changes to violet.

IDENTIFICATION

Corundum is distinguished from spinel and similar mineral substances by its greater hardness and density. Genuine stones that often pass for rubies are spinel, called balas or spinel ruby; the garnet, called the cape ruby; and the red tourmaline, called rubellite. These are not difficult to determine in the rough, as the crystals have entirely different shapes from that of the ruby.

With a little practice it is not very difficult to tell genuine stones in the rough; but only an expert can tell a genuine cut stone from a synthetic, at a glance, and as a rule it is necessary to use a microscope. This instrument is the only one of real value in determining gems, as it permits inspection of the structure, shape, and arrangement of the inclosed bubbles. Spherical bubbles and a wavy concentric structure signify a synthetic stone and angular bubbles and striations a genuine stone. The synthetic stone appears even clearer and altogether more perfect, whereas, the genuine is seldom free from some flaw or blemish. Striated structure in the genuine gives a sheen or silky luster when viewed by reflected light. The real stone is seldom perfectly round but is slightly elongated, whereas the synthetic is generally circular.

According to Calhoun[3/] gems may be determined as follows:-

> To facilitate the determination of rubies in the field, a thallium silver nitrate solution in water, having a specific gravity of 4, is prepared and carried in a small vial in the vest pocket. Any stone that floats on this solution is not a ruby, as the latter will just sink in the solution. The diochroscope is a tiny and inexpensive instrument which can be carried in the pocket. By holding the stone with a pair of tweezers before the lens of the diochroscope, two images of the stone will be seen side by side. If the position of the stone is then rotated so that different planes of the crystal come into view, the images will change color from pink to deep red in the case of the ruby, whereas the color in the case of spinel and garnet will remain unchanged. Red tourmaline or rubellite also shows the variation in color, but a difference in specific gravity and hardness from the ruby will aid in making the determination.
>
> Without the aid of the diochroscope one can obtain similar results with a white card. Place the gem in the direct sunlight and hold a white card a few inches from it in the direction of the light so as to get as bright a reflection as possible from the stone on the card. If the stone

3/ Calhoun, A. B., Burma- An Important Source of Precious and Semi-Precious Gems Eng. and Min. Jour., vol. 127, May 4, 1929, pp. 711-712.

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is a ruby, a double image of the reflecting surface will appear, and if the stone is turned, these pairs of reflections will stay together and not separate. This behavior is caused by the fact that the crystal is a double-refracting one. Diamond, spinel and garnet would give but a single image, as they are single-refracting crystals. A more expensive instrument which will determine quickly and accurately the character of any stone is the refractometer. This instrument determines the index of refraction of the stone, and on comparing the index obtained from an examination with a carefully prepared table accompanying the instrument, the name of the stone is identified.

The above methods will aid in differentiating the various stones from each other but not from the synthetic ones. As has been mentioned, a microscope is necessary to identify synthetics, as they are now being made with all the optical characteristics of the genuine.

SUBSTITUTES

Before artificial stones were perfected reconstructed stones were substituted for the genuine. These were produced by fusing fragments of the natural material. At first such stones were not clear and were poor in color and brittle, but later reconstructed rubies were much improved and found a ready market in France, Germany, India, and America. To-day reconstructed rubies are no longer manufactured to any extent, as they have been displaced by artificial stones.

Gaudin was the first to attempt to make artifical rubies; in 1837 he succeeded in producing microscopic stones by fusing alum at high temperature, adding a little chromium as a coloring agent. Later others, including Fremy and Verneuil, manufactured artificial rubies, but not until 1902 did Verneuil announce a process by which they could be produced on a commercial scale.

After success had been attained in the manufacture of rubies attempts were made to produce sapphires. Finally, early in 1910, small proportions of titanic acid and ferric oxide were added to alumina, and scientific sapphires were produced as a result. These stones, known as "hope sapphires", were manufactured by the Hellerite Co. of Paris under the direction of Prof. Verneuil.

Pure alumina treated by the Verneuil process yields white sapphires, but by adding up to 7 per cent of chromium oxide rubies in varying shades may be obtained. Blue sapphires may be made similarly, and about 2 per cent of the iron oxide and 1 per cent of titanium oxide are used as coloring matter.

In certain respects artificial rubies and sapphires manufactured by the Verneuil process are identical with the natural stones. Aside from the fact that they are far less costly, however, they do differ. The distinguishing features are structure lines, uneven distribution of color, cloudiness, brittleness, internal cracks, and lack of definite orientation of the cut stones.

Comparatively large quantities of cut artificial rubies and sapphires are used as jewels in watches and in scientific apparatus where hard bearing surfaces are required.

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HISTORY

Rubies undoubtedly were known to the ancients under various names. Before mineralogy became a science and chemistry could determine the character of minerals by their composition stones were named according to their color. "Carbunculus," a fiery red stone, included spinels, garnets, and finely colored ruby, types that were separated and distinguished as their several qualities became known. The Greeks wrote of a red stone called "anthrax" which no doubt was the stone we know as the ruby.

At one time all colored stones were called rubies and were distinguished by a prefix of color. Sapphires were known as "blue rubies." Some think that the "adamas" mentioned by early Greek writers was a corumdum and not a diamond, and probably the name was applied to both. They called any lustrous stone, that was colorless or nearly so "adamas" and any fiery red stone "carbunculus," "lychnis," or "anthrax," although either may have been ruby, spinel, or garnet.

In India the earliest references to the famous ruby mines in the Mogok district go back only to 1597 A. D., when the king of Burma first secured control. His descendants worked these mines intermittently to 1885, when they were leased to a French firm. A few years later, however, after Upper Burma was annexed by the British, the mines were leased to an English firm. About 1889 a concession was granted to the Burma Ruby Mines Co., which has subsequently worked them under a long-term lease from the British Government. During the last few years these mines of the Mogok district have contributed as much as 185,000 carats annually of beautiful rubies, sapphires, and spinels[4/].

OCCURRENCE

Rubies and sapphires occur in metamorphic rocks, particularly metamorphosed limestones, gneisses, and schists, and in placer deposits. They also occur in igneous rocks--notably basic rocks--including nepheline syenite and peridotite. The associated minerals include spinel, tourmaline, cyanite, magnetite, chlorite, and nephelite.

In Burmese mines rubies occur in banks of crystalline limestone, associated with granitic and gneissose rocks. Like other kinds of corundum, rubies undergo alteration under certain conditions. Sapphires and a number of other gem stones are found chiefly as pebbles or rolled crystals in alluvial deposits, as in Ceylon, occur with garnet and other minerals in glacial deposit and probably have been derived from dikes of igneous rocks, notably andesite and lamprophyre.

MINING METHODS

Ordinarily methods of recovering rubies and sapphires are rather primitive and generally open-cut methods are used. In Burma the native method on the flats was to sink to bedrock a small vertical shaft 4 or 5 feet square, locally known as a twinlon. The dirt was raised in baskets to the surface by crude bamboo hoists, with which natives were able to operate to a depth of 70

4/ Calhoun, Allan B., work cited, p. 708.

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feet, then washed in baskets to separate the precious material from other foreign particles. On account of the large amount of water in the valleys during the wet season this primitive type of mining could be employed only during the dry season.

For hillside mining the natives used a different system. A ditch was dug around the side of the hill to serve as a canal through which the water could run down from the mountain streams. In this manner the alluvials could be washed down into the sluices below for separation and final treatment. This kind of mining could be carried on during the wet season only, as it depended strictly upon running streams.

The Europeans employ a different method in Burma, sinking pits and using centrifugal pumps to handle the water. The surrounding ground at each level is excavated by pick and shovel and the material then hauled by trucks up an incline to the washer. However, in mining the deeper alluvials close to the town of Mogok a different system is necessary, as the cost of pumping would be prohibitive. Here a drainage tunnel 7 feet square in cross section and 5,400 feet long has been driven to tap the bottom of the valley.

A large amount of the material is handled with pick and shovel. After the ore is broken sluice boxes carry it to the mills, so that it is partly cleaned by the time it arrives. Impurities are then removed by further washing processes.

CLEANING

All impurities that are entirely separated from the particles of corundum are removed by the washing process, but those that remain attached to the particles or grains after such washing have to be removed by apparatus known as the screw or scouring machine. After grinding by such a machine the particles are washed again, and a scouring motion is kept up until all impurities are gradually worn away and carried off by the stream of water; four to eight hours are required before a clean product is obtained.

DRYING

After washing the product is removed, allowed to drain overnight on inclined floors, elevated to the second floor of the mill, and then dropped vertically 20 to 30 feet down the stack of a furnace. At the bottom of the furnace it strikes an inclined surface and slides into an iron box.

By another method the wet product is thrown in at the upper end of an iron cylinder open at both ends, which revolves about a coil of steam pipes. As one end of the cylinder is lower than the other the wet mass is alternately carried up by the revolving cylinder and dropped on the hot coil of pipes; then it is worked toward the lower end, whence it is conveyed to the sizing room. Here it is automatically screened to various sizes.

Some mills are completely equipped for gravity concentration; jigs are used for the coarser sizes of the crushed ore and either vanners or shaking tables for the finer sizes. This method works very satisfactorily and yields

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a nearly clean product. Minerals such as garnet or pyrite, which are likely to remain with the corundum in the concentrates, can be separated magnetically. It is said, however, that these purely mechanical methods are likely to result in considerable loss.

TREATMENT

In Burma a hydraulic system is now in use. Gravel pumps raise the material to sluices, then it is passed over a screen. Calhoun[5] describes the operations as follows:-

> The fine material, 2 inches and under, passes into a 10 by 60 ft. sluice box, where the concentrates are caught on riffles. These concentrates are cleaned up at intervals and carried to the sorting house. Sorting of the concentrates from the washers and the sluices is done by coolies in wire masks under a guard of Gurkhas with European supervision. The concentrates are put through revolving screens of different sizes and then into a pulsator and panned until the rubies and other valuable stones are on the bottom. The pan is then turned upside down and the good stones are picked out. Although the coolie wears a wire mask and is watched by the Gurkhas and Europeans, he nevertheless manages to purloin some good stones. The tailings goes outside the fence, where women, who have acquired a hereditary right, sort it over and pick out small rubies and other stones of some value.

DOMESTIC PRODUCTION

Fine rubies have been found in the crystalline rocks of North Carolina, and both rubies and sapphires occur in the river sands along the upper Missouri River near Helena, Mont. Sapphire mining in Montana, however, has been about the only gem-mining enterprise that has been carried on in the United States without interruption for any extended period. The New Mines Sapphire Syndicate, an English company, operated continuously for many years in the Yogo district of Judith Basin County, Mont.; but on account of the reduced demand for stones under 1 carat this company has been reducing its output for several years, and in 1929 operations were suspended entirely.

Production for this company for recent years is reported as follows[6]:-

Table 1. - Sapphires produced by the New Mines Sapphire Syndicate during 1924-192

Year	For gem purposes		For mechanical purposes		Total	
	Carats	Value	Carats	Value	Carats	Value
1924	46,950	$20,263	278,317	$5,566	325,267	$25,829
1925	54,495	29,138	211,873	4,237	266,368	33,375
1926	42,469	19,000	179,895	3,498	222,364	22,498
1927	6,451	4,638	83,235	222	89,686	4,860

Sapphires of industrial grade have also been mined at the rate of 20,000 ounces a year on the west fork of Rock Creek, Granite County, Mont., by the American Gem Syndicate.

5/ Calhoun, A. B., Work cited, p. 711.
6/ Kunz, Geo. F., Precious and Semiprecious Stones: Min. Ind., 1929, p. 550.

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INDUSTRY IN FOREIGN COUNTRIES[7]

Corundum fit for gem stones comes principally from Ceylon, Burma, Siam, Australia, and Montana. However, smaller quantities of both rubies and sapphires, have been found in other localities. The value of the output from these countries varies greatly from year to year, and statistics for the total volume or the value of the output of natural stones are lacking. Artificial stones are manufactured principally in Switzerland, France, Germany, and Italy. A few years ago 12 plants were producing these artificial[8] gems, and the daily output was said to have been 600,000 to 750,000 carats.

Burma

The Mogok mines of Burma, India, have been the chief source of rubies for years. Even when the Burma Ruby Mines, Ltd., originated in 1889 this district was noted for its "pigeon's blood" rubies. From 1889 to 1925 the total output of this country was about £ 1,775,000. The output of rubies from these mines has been declining since 1924, and it was thought that the supply had become exhausted. The value of the production in 1927 was £ 8,806, as compared with £ 8,059 in 1926, but the increase was said to have been due to discoveries of sapphires, which supplemented the output of rubies considerably. The mines have been operated on a restricted scale by a mere skeleton of the former organization.

During 1928 exceptional finds were made at View Point, about 10 miles from Mogok. A large ruby said to be worth £ 24,000 was discovered. The ruby output for the Mogok mines for 1928 was valued at £ 9,118, and on August 24, 1929, a 96-carat ruby was found. In 1928 sapphires from the Mogok mines were valued at £ 4,093 as compared with £ 12,052 in 1927. In August, 1929, a 950-carat sapphire was discovered in these mines, and in May, 1930, a 630-carat stone was found. The Mogok mines also produced a small amount of spinel, the value of which decreased from £ 334 in 1927 to £ 36 in 1928.

At the request of the Burma Government a geologist from the Indian Geological Survey surveyed the gem industry. His report indicated that the depression in gem mining in Burma was due to numerous causes, not to exhaustion of the gem-bearing deposits of the Mogok stone tract, and that other valleys in this stone tract merit fuller exploration than they have received so far. He recommends hydraulic mining to prove their value rather than the hand methods hitherto employed. In his opinion the greatest possibilities for the future will lie in large-scale treatment of the hillside deposits. He suggests that that stretch of country usually known as the "Western Slopes" should receive first attention, because mining by natives in the past indicates a gem-bearing region of great extent.

With the opening of new fields a number of rubies of excellent quality have come into the market. Even when turbid in color these "star rubies"

7/ Data taken largely from annual chapters on Precious and Semiprecious Stones in Mineral Industry, by George F. Kunz.

8/ Kraus, E. H., and Holden, E. F. Gems and Gem Materials: New York, 1925, p.104.

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Large first-class "blues" are becoming very scarce among the Queensland sapphires produced, consequently the Gem Miners' Association decided to locate new country, but unfortunately this enterprise was not successful.

New South Wales

In 1927, the Heiser Burmah Sapphires (Ltd.) started operating a dredge on sapphire ground near Inverell in New South Wales, treating the dirt in sluice boxes. Its operations proved so successful that the company began operating its own cutting plant and developing a sapphire-cutting machine. Sapphires totaling 3118 ounces in weight were produced in New South Wales in 1927.

Ceylon

Of all gems found in the Island of Ceylon, sapphires are the most plentiful. Recently several very valuable stones were found in the gem fields at Palmadula, which is about 12 miles from the town of Ratnapura. A remarkable find was made here about 1924. Sapphires and other gems valued at some $297,000 are said to have been taken from the Ratnapura district. In Ceylon, as in Burma, rubies are found associated with the sapphires.

Siam

Siam also has been producing sapphires of exceptionally fine quality. A number of unusually good stones have been produced quite recently, and the value of the output has been improved greatly.

During the fiscal year 1923-24 uncut sapphires valued at about $140,000 were exported to foreign countries. These stones were thought to have come from the districts of Krat and Chautaboon. Over 70 per cent of these went to Great Britain, while most of the remainder went to India, France, and the United States. During the fiscal year 1924-25 rough sapphires from Bangkok were exported, mostly to Great Britain. However, these stones were valued at only 54,700 ticals (somewhat over $20,000), as compared with 379,550 ticals in the preceding year.

Since June, 1927, the Bo Poi area of South Siam has been producing sapphires of high quality. The best stone, peacock blue with a purplish tint and free from all defects, weighed over 40 carats in the rough and 10.87 carats when cut.

MARKETS AND PRICES

In New York fine Burma rubies weighing 7 to 9 carats are worth $3,000 a carat, and sapphires weighing 20 to 30 carats and perfect in color command a price of $1,000 to $1,500 a carat, while in Rangoon it is impossible ever to state the prevailing prices. The native dealers have no fixed prices, and every stone must be bargained for. However, pigeon's blood rubies about one-half carat in weight will cost $1,000 if the stone is flawless or nearly so. Fairly good rubies can be purchased for $150, while sapphires may be purchased as low as $6 and up to $125. On the other hand, exceptionally fine stones may be worth as much as $1,500 per carat.

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In 1929, according to Kunz (Mineral Industry, p. 549), a 96-carat ruby was found in the Mogok mines and later sold for £ 7,500 or about $380 a carat. This stone was cracked down the middle, which would necessitate cutting it into two parts.

The best markets are European cities, particularly London. The Ruby Mines Co. ships practically its whole output to London, while most of the Queensland sapphires are disposed of through dealers in Paris or London. The New Mines Sapphire Syndicate of Montana ships the bulk of its output abroad for cutting and disposes of its stocks through London and Paris markets. The finest stones are cut in London and Paris, while the inferior specimens are cut principally in Switzerland and from there distributed, being finally used for jeweling watches.

The average value of small gem sapphires (cutting under 1 carat), produced by the New Mines Sapphire Syndicate in Montana in 1927 was a little over 70 cents a carat, and its industrial stones were valued at only a little over a quarter of a cent a carat. Although the sales value of stones for cutting purposes was considerably greater than the receipts in 1926 and previous years the price obtained for industrial stones was scarcely one-eighth as much.

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